# ATLAS: M&O, Commissioning, Performance

**BNL DOE REVIEW, MAY 2010**

**S. RAJAGOPALAN**

# OUTLINE

- **An Executive Summary:**
  - Detector, Software & Performance
  - Re-emphasizing the points made at the plenary session.

- **Details**
  - Liquid Argon (LAr)
  - Cathode Strip Chambers (CSC)
  - Trigger
  - Performance

- **Summary**

- **Highlighting BNL role in each of these activities.**

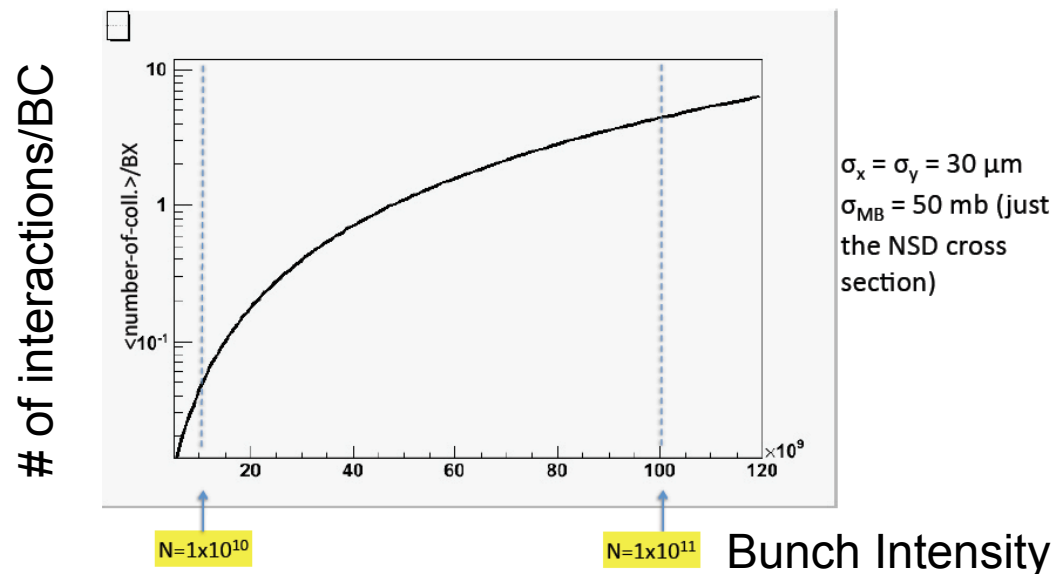# ATLAS: Data Collection



- Collected ~ 8 nb$^{-1}$ with stable beams

  - with peak luminosities of $6 \times 10^{28}$ cm$^{-2}$ s$^{-1}$

  - Most of this coming this past weekend: 5/15

- 96.5% of luminosity delivered with stable beams has been recorded.

- Driven primarily by minimum-bias triggers.
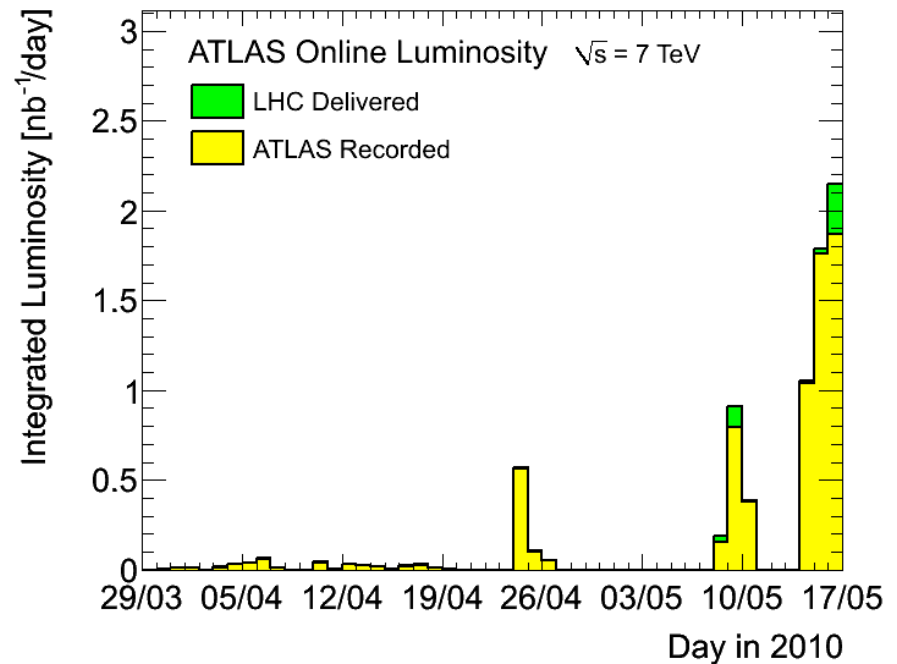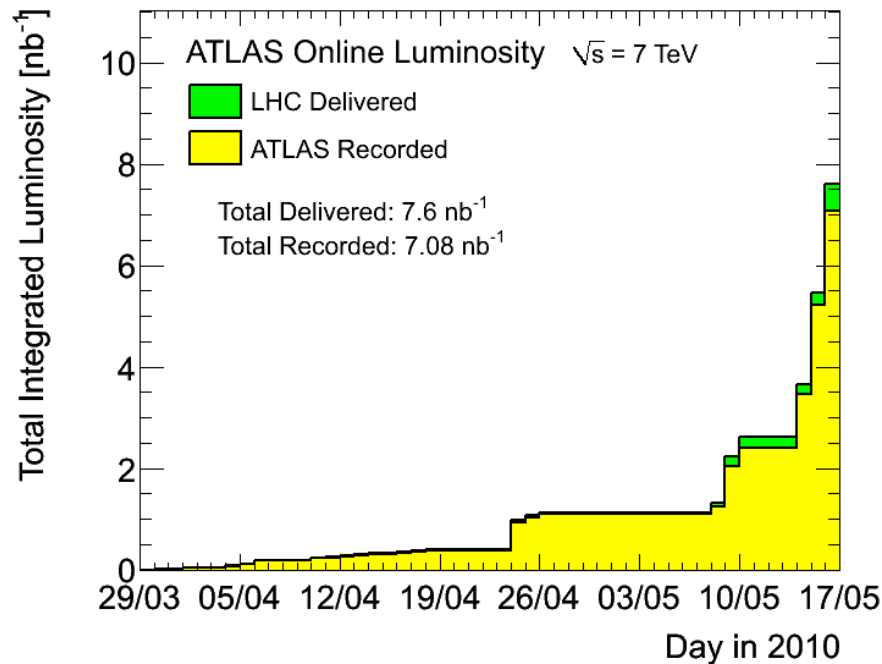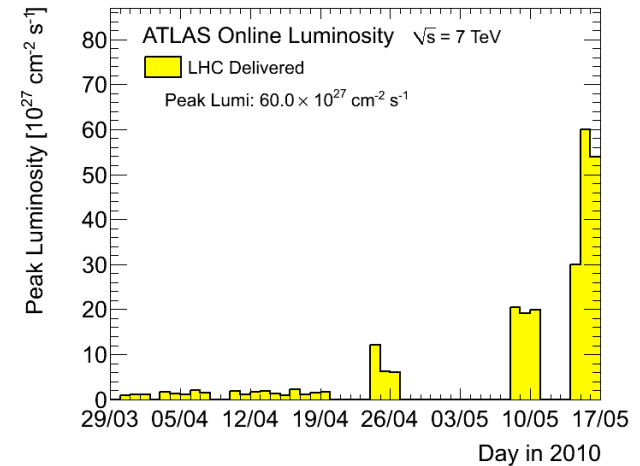
# LHC plans in the coming months:

- Successfully operating now with $2 \times 10^{10}$ protons/bunch.
  - With up to 3 colliding bunches in machine.
- Plans to double the total beam current ~ every two weeks
  - Proposal to increase bunch intensity up to $10^{11}$ protons/bunch
    - Gives rise to about 4 to 5 interactions/crossing
  - Or twice the number of bunches with half the protons/bunch
    - More manageable pile-up conditions



$\sigma_x = \sigma_y = 30\ \mu m$
$\sigma_{MB} = 50\ mb$ (just the NSD cross section)

# of interactions/BC

\<number-of-coll.\>/BX

N=1x10^{10}     N=1x10^{11}     Bunch Intensity

# LHC plans in the coming months:

- Last Weekend (5/15):
  - 3 colliding bunches each with 2 x $10^{10}$ protons.
  - Peak Luminosity at 6 x $10^{28}$ $cm^{-2}$ $s^{-1}$.
  - Collected > 3 $nb^{-1}$ over the weekend.

- Until end of June:
  - Increasing intensity to $10^{11}$ protons/bunch
  - Increasing to 16 bunches and peak L up to $10^{30}$ $cm^{-2}$ $s^{-1}$ (mid-June)
  - Expect 1 $pb^{-1}$ by end of June

- Longer time-scale:
  - Intermittent running at lower bunch intensity/higher # of bunches possible to have lower pile-up samples available for studies.
  - Increasing inst. luminosity to $10^{32}$ $cm^{-2}$ $s^{-1}$ by year end.
  - 100 $pb^{-1}$ accumulation by year end
  - 1 $fb^{-1}$ by end of 2011 (before first major shutdown).

# DETECTOR

- Detector R&D, construction and operations has been a key strength at BNL for the past several decades.
    - Significant expertise, in collaboration with Instrumentation Division.
- In ATLAS, our contributions include:
    - Liquid Argon Calorimeter
        - Barrel Cryostat, cryogenics
        - Signal Feedthroughs
        - Barrel Cold Electronics
        - Front-end electronics and crates
        - Low Voltage Power Supplies
        - System Tests
    - Cathode Strip Chambers
        - Production of all chambers
        - On-detector electronics

Continue to maintain and operate these detectors

# SOFTWARE

- Significant contribution early on in Simulation & Reconstruction software:
  – Coupled to our interests and expertise in detector sub-systems
  – Driven by the need to understand detector performance.
  – Today, we continue to be involved in detector software, but naturally diversified in contributing to related performance studies.

- We continue to contribute to Core Software development including:
  – Core software for offline reconstruction (Athena)
  – Database
  – Distributed Analysis and production software.
  – Driven by our need to adapt and use of the software components remotely. In collaboration with Physics App. Software (PAS) group.
  – Much of this is U.S. ATLAS Operations program funded effort, but with active participation of core-program physicists.

# TRIGGER & PERFORMANCE

- Our interests and contribution to performance studies relate directly to our detector interests:
  - **electron/photons**
  - **jets**
  - **taus**
  - **muons**
- Involved in trigger performance and related software development.
- Experience from D0 has been critical to our successful contributions to ATLAS.
- Close collaboration with several groups, in particular nearby U.S. ATLAS institutes, including Stony Brook.

# LEADERSHIP roles in ATLAS and U.S. ATLAS

- ATLAS:
  - ATLAS Trigger Coordination (Rajagopalan)
    - One of the five principal activity areas in ATLAS
  - ATLAS Liquid Argon Software & Data Preparation Coordination (Ma)
  - Current ATLAS Physics Group Conveners:
    - SUSY, Higgs, Heavy Ions (Redlinger, Assamagan, Steinberg)
  - ATLAS Jet Trigger (Begel)
  - ATLAS Distributed Analysis Operations (Klimentov)
  - Membership in several ATLAS steering groups.

- U.S. ATLAS:
  - U.S. ATLAS Computing & Physics Support (Wenaus)
  - U.S. ATLAS Deputy Program Manager (Gordon)

- These leadership positions reflect our successful role in ATLAS and our ability to make significant contributions to LHC physics.

# Role in U.S. ATLAS

- Our expertise in:
  - Detector sub-systems, Software, Trigger and Performance
- Provides a solid platform that will allow us (BNL) to participate in  LHC physics analysis.
- Allows us to play a vital role in assisting U.S. physicists with their analysis program:
  - Several universities do not have the same level of expertise in underlying software and particle identification necessary to participate effectively in a physics analysis.
  - Our responsibility as a U.S. ATLAS Analysis Support center necessitates the need to build an "expertise foundation".
  - Frequent "jamborees", weekly meetings involving several institutes, personal one-to-one interactions and communication via e-mails etc. provide the vehicle for this assistance.

# ATLAS LEVEL OF EFFORT (FY10)
## Core Research Program Physicists

| Software | | Staff | Post-Doc | Total |
|---|---|---|---|---|
| | Calo | 0.7 | 0 | 0.7 |
| | Muon | 0.1 | 0 | 0.1 |
| | Core | 1.3 | 0 | 1.3 |
| | Trigger | 0.1 | 0 | 0.1 |
| | **Total** | **2.2** | **0** | **2.2** |
| M&O | | | | |
| | LAr | 0.3 | 0.95 | 1.25 |
| | Muon | 0.4 | 0.2 | 0.6 |
| | TC | 0.2 | 0 | 0.2 |
| | **Total** | **0.9** | **1.15** | **2.05** |
| Performance | | | | |
| | egamma | 0.4 | 0 | 0.4 |
| | Jets | 0.1 | 0.25 | 0.35 |
| | Tau | 0.4 | 0 | 0.4 |
| | Muon | 0 | 0.2 | 0.2 |
| | Trigger | 1.15 | 0 | 1.15 |
| | **Total** | **2.05** | **0.45** | **2.5** |
| Physics | **Total** | **3.75** | **2.2** | **5.95** |
| R&D | **Total** | **3.4** | **0.1** | **3.5** |
| Support | **Total** | **0.8** | **0** | **0.8** |
| | | | | |
| **Effort Total** | | **13.1** | **3.9** | **17** |

3 staff and 3 post-docs are currently based at CERN

# Operations Tasks

- There are three classes of operations task:
  - Type 1: ATLAS Control Room Shifts (55 per day)
  - Type 2: all other shifts, on-call, validation, … 145/day
  - Type 3: Expert operation tasks, ~ 600 FTE.
- Each institution is expected to contribute to each of these categories proportional to the number of authors.
- For 2010, this share is about:
  - Type 1: ~ 7 shifts per author
    - Requires travel to CERN, putting additional burden on CERN based people
  - Type 2: ~ 19 shifts per author
    - Includes remote data taking shifts
  - Type 3: ~ 0.25 FTE per author.
    - We have ~4 of 17 FTE devoted to M&O + Software activities
- Expect the right share to balance over ~ 3 year period.
- We are meeting our share of Type 3 tasks, but fall short in Type 1 & Type 2.

# BNL contribution to recent public notes:

- BNL is contributing to several ongoing performance and physics analysis.

- As an indication of our success, ATLAS produced a "book" on 12/28/2008:

  **"Expected Performance of the ATLAS Experiment:**

  **Detector, Trigger and Physics"**

- Out of 76 sections WE:
  - Contributed to 21 sections
  - Were reviewers of 5 sections
  - Were editors of 6 sections
    - Muon Reconstruction and Identification: (Adams)
    - Calibration and Performance of the EM Calorimeter (Snyder)
    - The ATLAS Trigger for Early Running (Rajagopalan)
    - Data Preparation for the ATLAS HLT Calorimeter Algorithms (Damazio)
    - Diboson Physics Studies (Ma)
    - Prospects for SUSY Discovery Based on Inclusive Searches (Paige)

# THE DETAILS

# LAr: Software, Maintenance & Operations

- Low Voltage power supply (Chen, Damazio, Lanni)
  - Design, Production – backup, Maintenance & Operations
- Software:
  - Electronic Calibration software & processing (Tarrade, Damazio)
  - Conditions database for online software (Majewski)
  - LAr Trigger software development (Damazio)
- LAr data quality/performance:
  - Understanding detector problems (Gadfort)
  - Assessing the performance of EM calorimeter with final state electrons (Tarrade)
- Leadership:
  - LAr Software & DataPreparation Coordinator  (Ma)
  - LAr Run coordinator (Majewski)

# LAr Detector Performance

Distribution of Cell Energy in EM calorimeter compared to Non-Diffractive MC
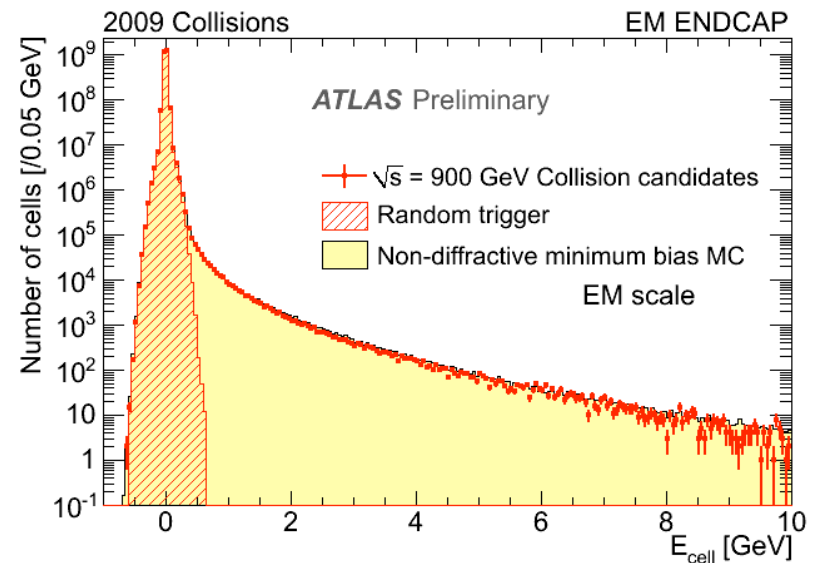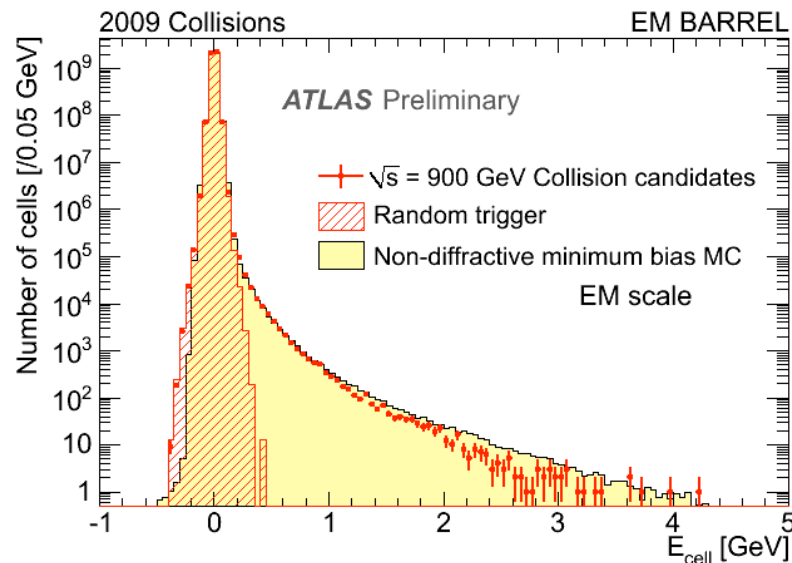


98.5% operational number of channels in LAr EM calorimeter

Low Voltage Power Supply:

- All 58 are currently operational (five of them have lost some redundancies)
- Backup LV PS prototypes evaluated, vendor selected for production (PRR)
- Installation during 2012 shutdown.

# MUONS: CSC

- BNL proposed, designed & built the detectors and on-detector electronics.
- We have full responsibility of the operation and maintenance of detector including services such as low and High voltage, cooling and gas systems.
- 98.5% of the detector fully operational.
- Readout limit extended to 63 kHz, now regularly part of online running.



Cumulative residuals, uncorrected
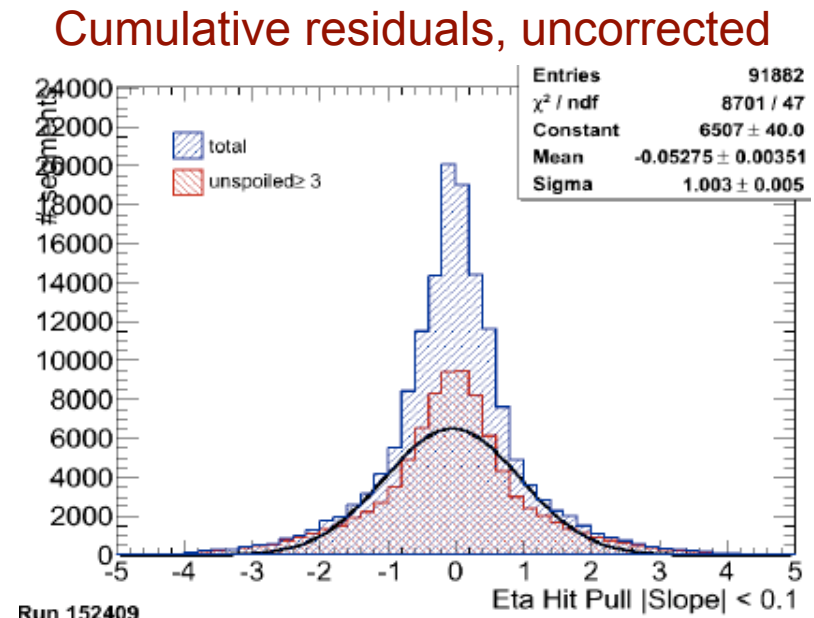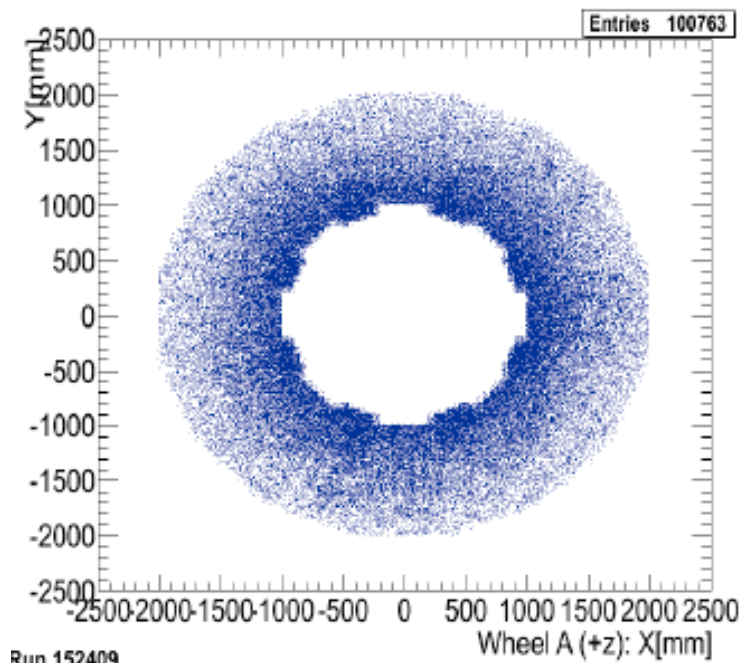
# Trigger: Software & Performance

- Overall Trigger coordination (Rajagopalan)
  - One of the five principal activity areas in ATLAS
- Jet Trigger coordination (Begel)
- Calorimeter trigger software (Damazio)
- Software tools to access trigger decisions during analysis (Begel)
- Measurement of trigger efficiencies: muons, jets. (Begel, Redlinger, Mete)

# Trigger operational from Day 1

- Peak Luminosity of $10^{27}$ cm$^{-2}$ s$^{-1}$.

- Primary trigger relied on MinBias trigger scintillator: MBTS_1 (requiring 1 of 32 scintillators)

- Most of High Level Trigger (HLT) was running in "monitoring" mode.

- Min-Bias HLT was enabled to actively reject during first fill.

- Recorded > 97% of delivered data with stable beams.



Trigger rates during first 7 TeV collisions
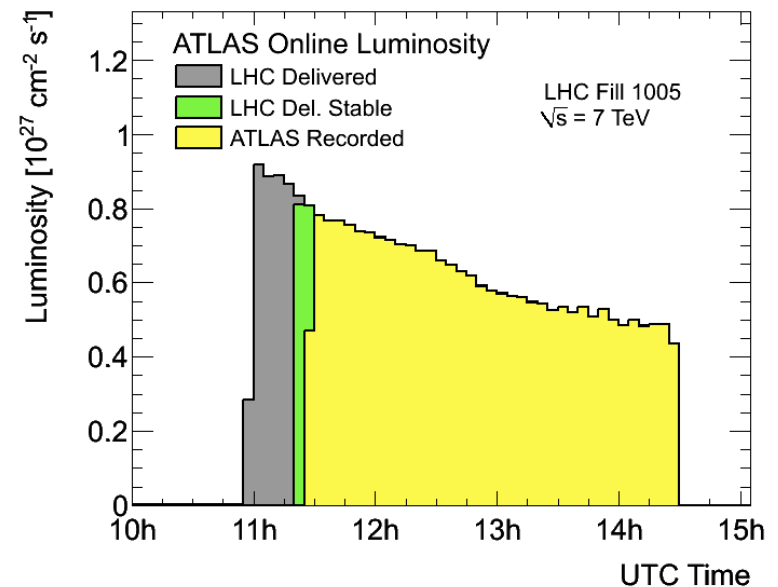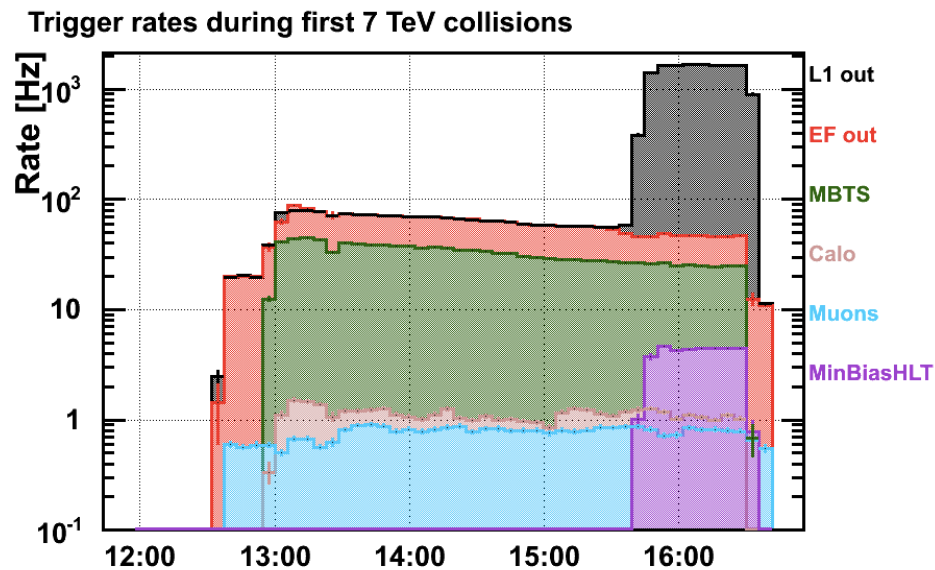
# Trigger performance studies
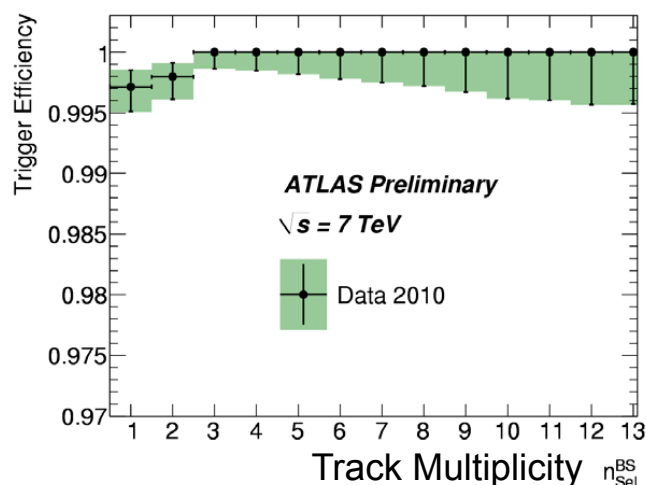


- Efficiency of L1 Minimum Bias trigger scintillator (MBTS_1 == requiring 1 of 32 scintillators) at 7 TeV.

- Determined using random trigger based on BPTX (beam pick-ups) with HLT space point ~~selection~~



Efficiency of L1 Jet cluster trigger J5 (5 GeV) at EM scale determined from min-bias data and compared to non-diffractive simulation
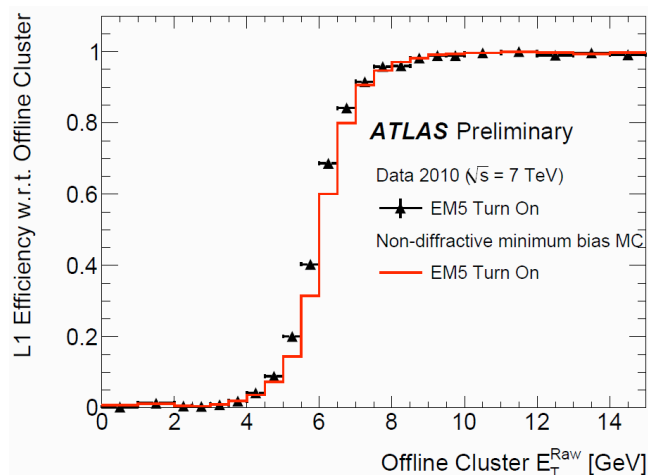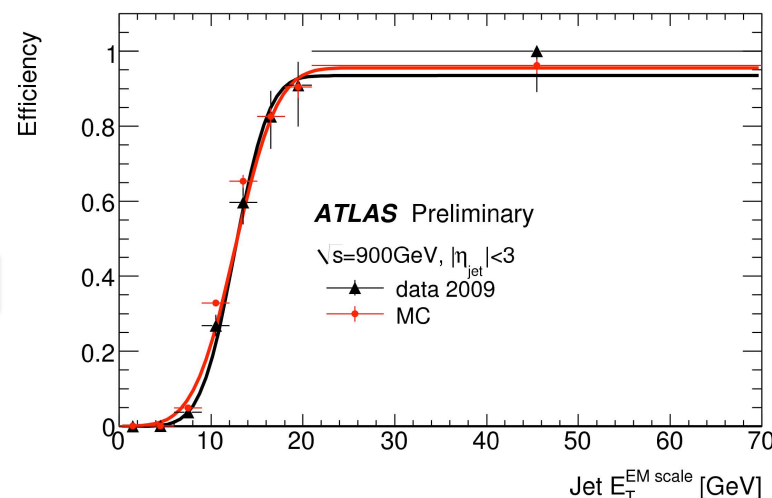


- Efficiency of L1 Electromagnetic (EM) cluster trigger, EM5 (5 GeV in 0.1 trigger tower).

- Determined from min-bias trigger sample requiring offline EM clusters and compared to non-diffractive simulation.

# Trigger commissioning and plans

- Rely largely on min-bias triggers with low luminosity
  - Total output rate to disk ~ 200 Hz at 1.6 MB/event.
- Pre-scale min-bias keeping L1 Calo & Muon un-prescaled with increasing luminosity operating HLT in "monitoring" mode.
  - Until rates for L1 Calo + Muon ~ 150 Hz.
- Trigger menus developed to adiabatically transition to higher luminosities.
  - All items controlled with pre-scale sets that can be updated during a run
- Rate estimation with data ongoing, bootstrapping to higher luminosities.
  - Serve as input in developing pre-scale sets for higher luminosities.
- Efforts underway to understand the effects of pile-up on trigger.
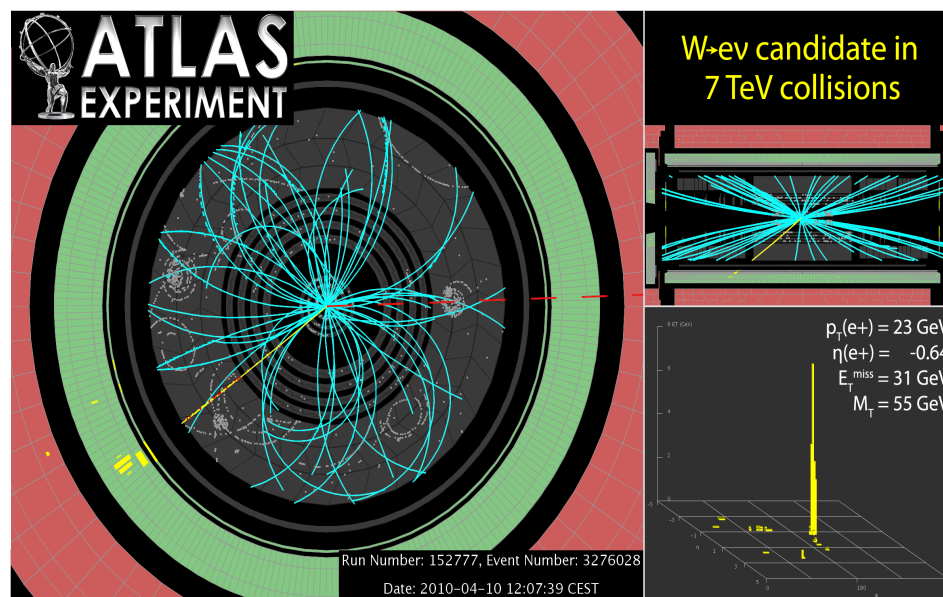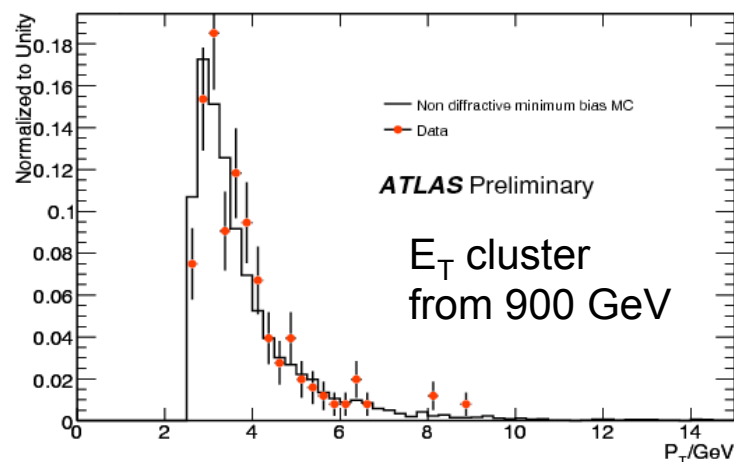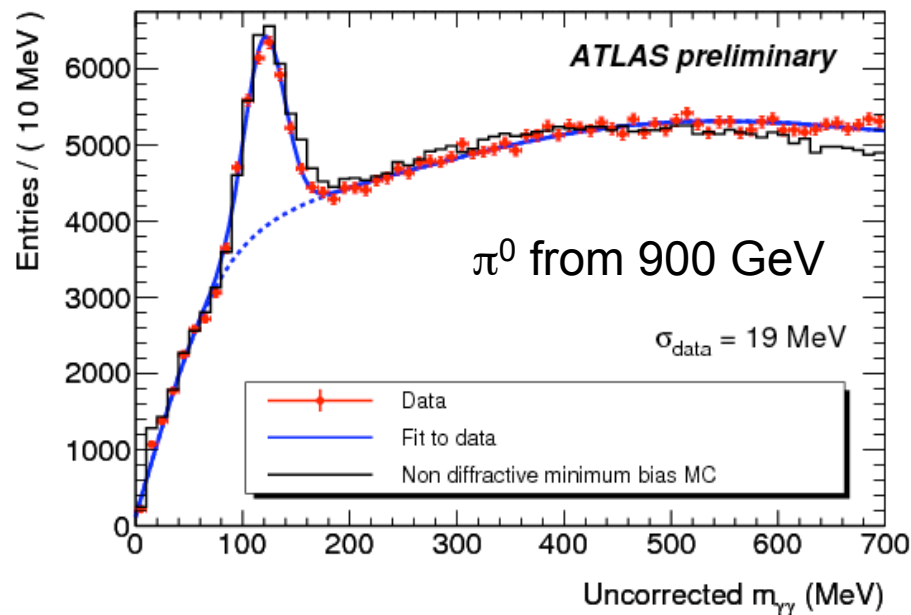
# Software

- D3PD maker
  - BNL developed the common framework for ntuple production for performance and physics, allowing physics and performance groups to "plug-in" their tools.
  - BNL also developed the software/ntuples for e-gamma studies.

- AthenaRootAccess
  - Allows access to reconstruction output directly from ROOT.

- StoreGate
  - Transient Data Model Infrastructure with the ATLAS reconstruction framework.

- Production & Distributed Analysis Software.

- Pile-Up and Overlay software.

- Contributions to LAr, Muon & Trigger software applications.

# e-gamma performance

Snyder, Tarrade

BNL personnel active in analysis of first e/gamma data: data/MC comparisons and pi0 search.

ATLAS analysis of early e/gamma data relies on NTuple code developed at BNL.



$\pi^0$ from 900 GeV

$\sigma_{data}$ = 19 MeV



$E_T$ cluster from 900 GeV



W→ev candidate in 7 TeV collisions

$p_T(e+) = 23$ GeV
$\eta(e+) = -0.64$
$E_T^{miss} = 31$ GeV
$M_T = 55$ GeV

Run Number: 152777, Event Number: 3276028
Date: 2010-04-10 12:07:39 CEST

# Muon software & performance

- Lead effort to commission and develop and maintain software for the CSC detector. Run weekly meetings.

- Software development for CSC Simulation & Digitization

- Validate muon performance in releases and report to physics validation

- Carry out studies to evaluate muon performance (efficiency, fakes, isolation, resolution, etc).

- Monitor MC reconstruction jobs

- All these strengthen our

ability to contribute to physics

with final state muons:

  – Inclusive muon cross section
  – W' to muons

Assamagan, Adams, Nikolopolous
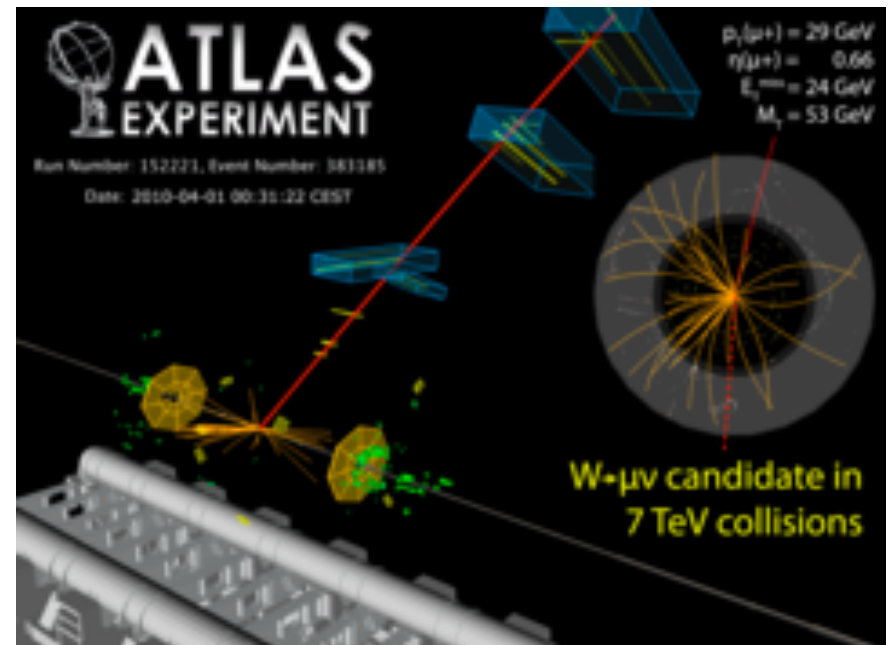
# Jets performance

- Principal Contributors: Begel, Ma, Majewski, Paige, Pleier in close collaboration with several other institutions.
- Jet Energy Scale (JES) using Global Calibration Weight scheme
- Determination of JES using tracks in jets; will be used as a cross check on systematic uncertainty for initial JES.
- Determining jet efficiency from data using track jets
- Understanding jet angular resolutions by comparing topoclusters with tracks
- JES corrections for non-isolated jets
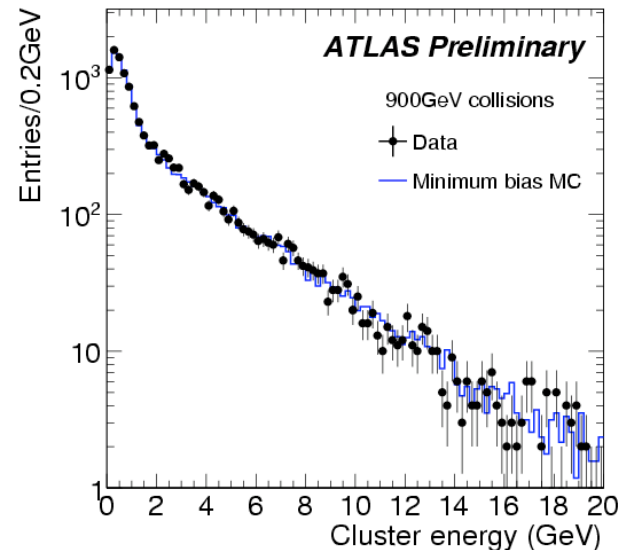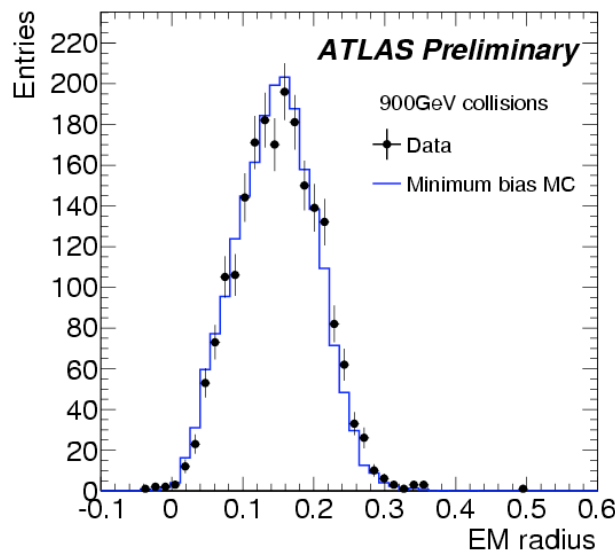- Jet Trigger performance

# Jet Performance





Di-jet Event at 7 TeV
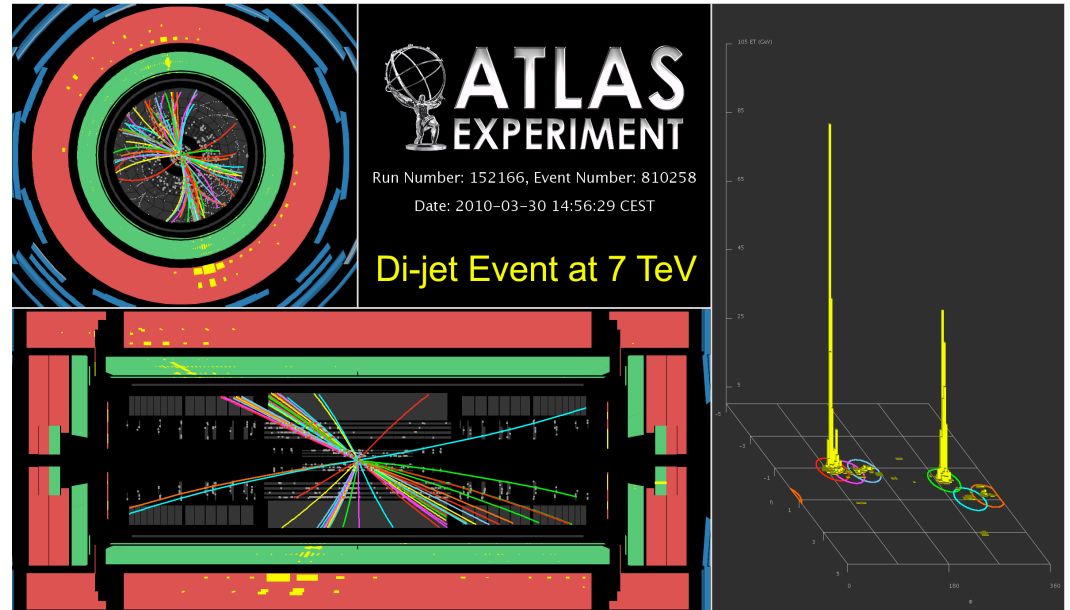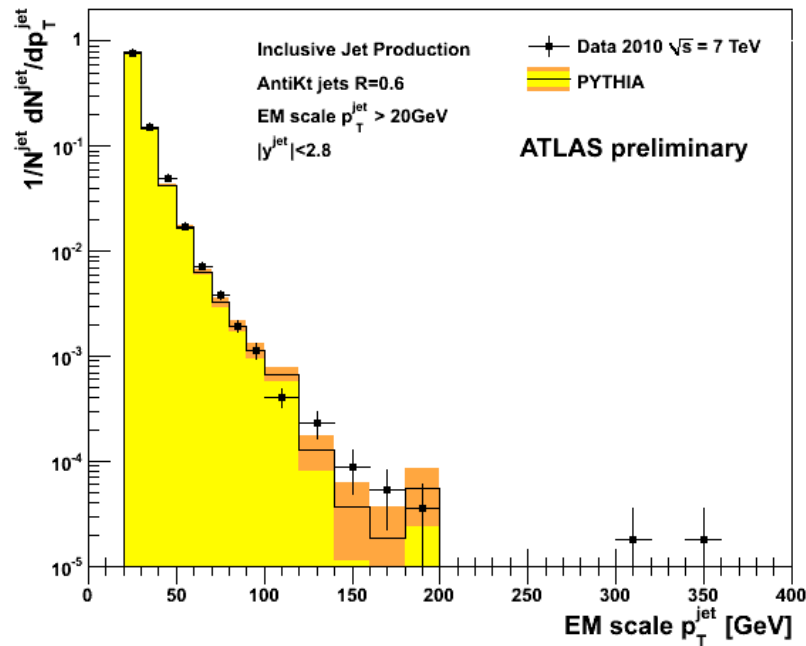


Inclusive Jet PT and ΔΦ distributions
Measured (black dots) at EM scale and
Compared to PYTHIA.
Only statistical errors are shown.
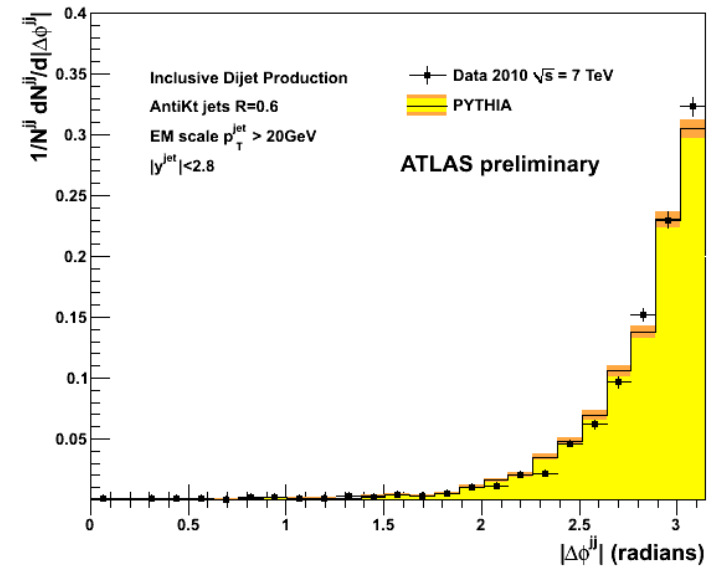
# Tau performance

Protopopescu, Tarrade, (Patwa)

- Current tau identification based primarily on cut methods.
- Need to explore more sophisticated methods to extract tau candidates, such as boosted decision tree and likelihood methods.
  - Significant experience from D0 on tau identification.
  - Develop, study and implement these methods in ATLAS
  - Leading naturally to involvement in $Z \to \tau\tau$ and VBF H $\to \tau\tau$ analysis

# Summary

- **BNL has a strong expertise in detector R&D.**
  - Has made major contributions to ATLAS LAr and CSC detectors
  - And continues to maintain and operate the detectors.

- **BNL has made significant contributions to related performance areas:**
  - Trigger, egamma, jets, taus and muons.

- **BNL has taken leadership roles in many of these activities.**
  - With memberships in ATLAS Management and several major coordination bodies.

- **BNL plays an essential role in U.S. ATLAS Physics Analysis Support activities.**

- **And BNL will use this established expertise to make major contributions to ATLAS discovery and precision physics and future upgrades to ATLAS detector.**
  - This journey has already begun.